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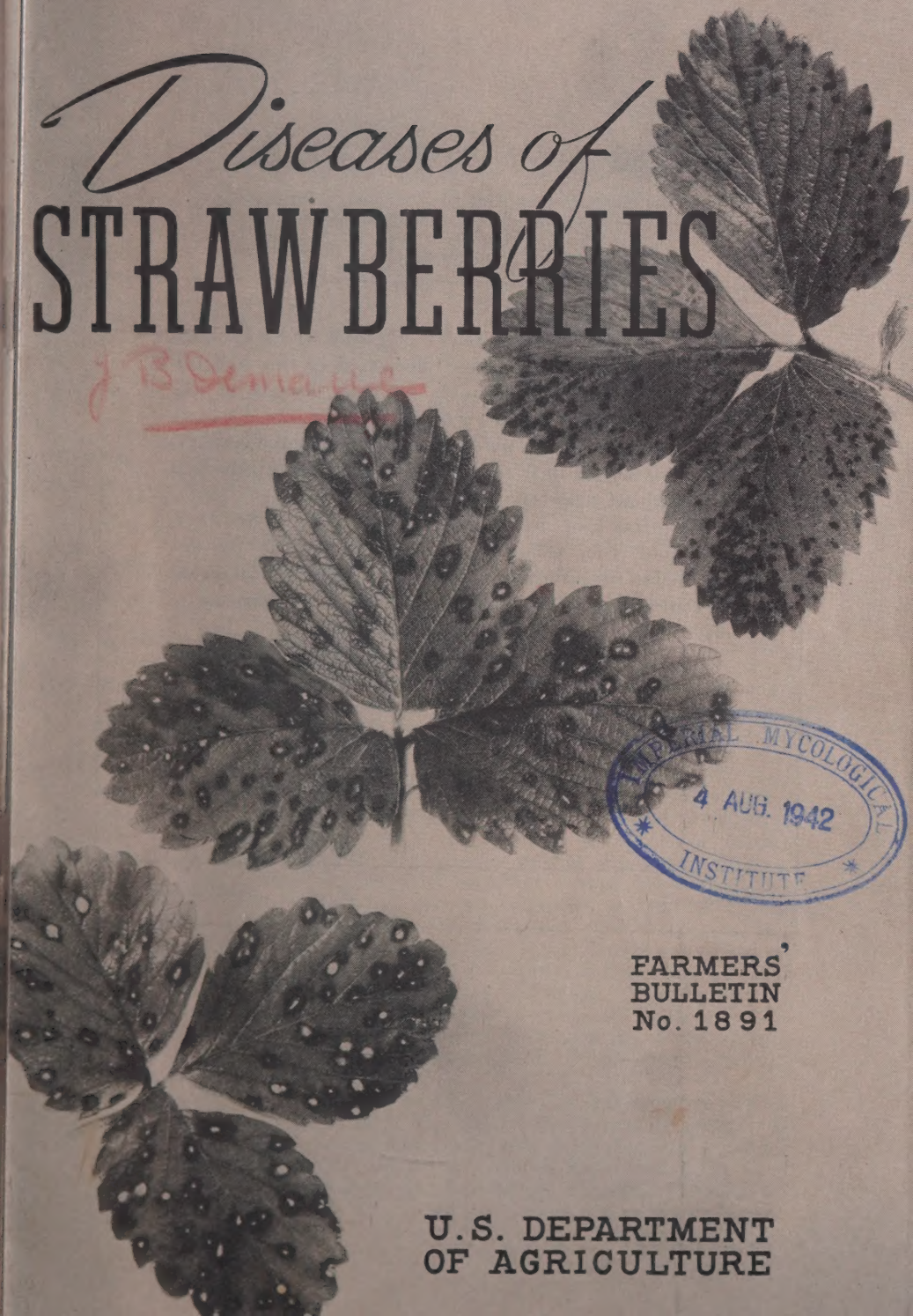
Diseases of STRAWBERRIES



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THE MOST IMPORTANT STRAWBERRY DISEASES are described and illustrated in this bulletin. Attack by fungi is responsible for most diseases of this crop, but nematodes and viruses cause some.

Foliage diseases are widespread throughout the country, but spraying for their control is not practiced except in a few southern strawberry districts.

Since leaf spot, leaf scorch, dwarf, red stele root rot, root knot, June yellows, and virus diseases may be distributed in the propagating stock, the most practical means of control are frequent renewal of fields and the use of disease-free plants for setting new fields.

Injury to plants by low winter temperatures and rotting of berries in the fields can be reduced by mulching and other cultural methods. Careful handling and adequate refrigeration will greatly lessen the losses from fruit rots that occur after picking.

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DISEASES OF STRAWBERRIES

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IMPORTANCE OF DISEASE-FREE STOCK

STRAWBERRIES to supply home demands and local markets are commonly grown in gardens and small fields in about all regions of the United States. The more important centers for commercial production are located in widely separated regions throughout the country, where climate and soil conditions are favorable for profitable production of berries.

Strawberries are grown under very different conditions as to rainfall, soil, altitude, drainage, length of growing season, temperature, and length of day, necessitating the use of different cultural practices and varieties adapted to those conditions. All of these factors directly or indirectly affect the presence or the absence of diseases.

Root knot, foliage diseases, and field fruit rots are more abundant in some southern strawberry districts, whereas the red stele root disease and root troubles resulting from low winter temperatures are either absent or of little importance there. The amount of rainfall and its distribution are important factors that influence the presence of fungus diseases in foliage, fruits, and roots. Temperature, at least in part, limits the red stele root disease and summer dwarf. The former is favored by low temperatures and the latter by high temperatures. Leaf variegation is unaffected by any known environmental factor.

At present virus diseases of strawberries are limited to regions where climatic conditions favor most the multiplication and persistence of insects that spread these diseases. Methods of planting and growing, length of harvest season, and the number of years that fields have been cropped also influence the amount of disease. Rotation of

crops, selection of disease-resistant varieties, and use of disease-free plants for setting new fields are all important practices which strawberry growers can use to assist in combating diseases, at a minimum cost.

The use of disease-free plants for starting new fields is of major importance. A grower may select a choice variety, plant in good soil, handle correctly other cultural details, and be favored with good weather, but if he should inadvertently introduce a destructive disease, such as red stele root disease, dwarf, or a virus disease, into his field with his propagating stock, his yield may be unprofitable. In this connection it may be said that the advantages that can be derived from the use of disease-free plants for setting new fields will be offset if the new fields of clean plants are adjacent to or near an infected old field. On account of the many variable and uncontrollable factors acting singly or in combination, recommendations for controlling diseases in one strawberry region may not be applicable in another.

Large centers of the strawberry-plant-growing or strawberry-nursery industry are confined to a very few restricted districts. Plants grown in these places are shipped to all sections of the country. Unless plant growers and the plant-inspection agencies of the States where the plants are grown appreciate the importance of producing disease-free plants, such districts can easily become centers for the distribution of disease to all parts of the country.

FOLIAGE DISEASES CAUSED BY FUNGI

There are several fungus diseases known to attack strawberry foliage, but only three are of sufficiently widespread importance to be considered in this bulletin. These three are commonly known as leaf spot, leaf scorch, and leaf blight. Although one or more may be found in nearly every strawberry field at some period during the year, the damage varies greatly, being influenced by weather, variety grown, and the amount of disease inoculum on the plants when set or carried over from the previous year. At some periods during the season, these diseases may be represented by a few scattered spots; however, at other times the spots may be so numerous as to kill many of the leaves.

LEAF SPOT

The leaf spot disease [1] is widespread, being found in almost all regions where strawberries are grown. It is regularly destructive in some sections of the Gulf coast region. In other regions its occurrence in an epidemic form is sporadic, such epidemics being determined by weather conditions favorable for the development and spread of the causal fungus during the period prior to harvest.

On the under side of the leaves the spots show as indistinct tan or bluish areas one-eighth to one-quarter of an inch in diameter and tend to be circular in outline. On the upper leaf surface the spots are first purplish in color, but later, as the affected tissues are killed by the fungus, their centers pale to tan and gray and finally to almost white, surrounded by a purplish border. The spots are conspicuous at this stage because of the contrasting colors against the green background of the leaf surface (fig. 1).

[1] Caused by *Mycosphaerella fragariae* (Tul.) Lindau.

The leaf and fruit stalks, stolons, and to some extent the calyxes or caps are attacked by the leaf spot fungus. Spots on these parts are similar in appearance to those on the upper side of the leaves. The fungus is also known to cause black spots on the berries. The disease on the berries is called black-seed and is described on page 22.

Under favorable weather conditions, clusters of spores emerge from the upper surface of the white spots, and rain scatters them to nearby leaves, where they may germinate and start new spots if the leaf tissues are susceptible and weather conditions are favorable. Undoubtedly they are carried over greater distance by birds, insects, farm implements, and the hands and clothing of workmen weeding the fields, spacing the plants, and picking the berries. Tests have

FIGURE 1.—Strawberry leaf spot on the upper side of leaves. Note the white centers and the dark borders of the spots.

indicated that wind is not an important agent for spread of spores. The fungus lives through the winter mainly in spots formed during the autumn and produces a new crop of spores the following spring and thus starts the disease anew.

Only the immature parts of the plant are susceptible to infection, and an epidemic of the disease is contingent upon the development of many new leaves during the occurrence of cool weather, accompanied by an abundance of moisture in the form of frequent dews or rains. During a combination of such conditions the disease sometimes becomes devastating, and a large portion of the leaves are killed.

As the leaves approach maturity they become more resistant to infection and after they have attained full size and lost their succulent texture, infections are less likely to occur, even under the most favorable conditions. If dry weather prevails during early spring when the new leaves are developing and expanding, very little spotting will occur; on the other hand, if there are frequent rains at that period

the leaves may be badly spotted during the blooming and the harvesting season. A spring application of a nitrogenous fertilizer, resulting in the production of an abundance of succulent foliage, may tend to increase the amount of disease.

Recommendations for Reducing Losses

For methods of reducing losses from leaf spot, see page 5.

LEAF SCORCH

The scorch disease [2] of strawberry leaves may be distinguished from leaf spot by the dark-purplish spots about one quarter of an inch in

FIGURE 2.—Strawberry leaf scorch on the upper side of leaves. The spots are dark purplish but do not have light-colored centers.

diameter without white centers (fig. 2). Since both diseases are so frequently found on the same plants, they are often considered by the novice as different stages of the same disease. Leaves at all stages of development, even the old mature ones, are susceptible to infection by the scorch fungus. Spores are produced in great numbers in tiny receptacles formed by the fungus on the upper surface of the leaves within the dark-colored diseased areas. The spores are distributed in about the same manner as the spores of the leaf-spot fungus and by the same agents.

Scorch is about as widely distributed as leaf spot and perhaps in the aggregate does more damage because it not only attacks the leaves, thus weakening and sometimes killing the plants, but also often does considerable damage to the caps, or shucks, petioles,

[2] Caused by *Diplocarpon earliana* (Ell. and Ev.) Wolf.

stolons, and fruitstalks. When the fruitstalks are attacked they are sometimes girdled; this causes the death of the flowers and young fruits. Occasionally the fruits are also affected, but this form of the disease is seen only when conditions are very favorable for infection. The effect on the fruit is not particularly noticeable except when the disease shows on green berries; then it appears as a superficial red or brown discoloration and flecking.

Recommendations for Reducing Losses

In spite of the widespread occurrence of foliage diseases in this country, spraying for their control is not generally practiced except in a few restricted districts. This is probably because the diseases do not occur regularly enough in most places to warrant the expense of spraying.

Leaf spot and leaf scorch both can be controlled satisfactorily by spraying with 4–4–50 bordeaux mixture. A spray schedule designed to prevent spotting of the foliage by one disease will be equally effective against the other. The object of spraying is to prevent the plants from becoming infected by the fungi, and it should not be considered as a cure. To be effective, the protective spray should be applied well in advance of the harvest season. The time to make the first application and the number of applications to be made for control will depend upon the region where the work is being done. In the Hammond, La., strawberry district, where spraying is regularly practiced by most strawberry growers, the first application is made during the first week in January and is repeated at approximately 10-day intervals until the first week in March. This schedule requires about six applications for the season.

Spraying strawberry fields in southern Louisiana is considered a very profitable practice. One year when foliage diseases caused heavy damage in unsprayed fields, the Louisiana Agricultural Experiment Station demonstrated experimentally that by spraying the yield of berries was increased at the rate of 219 crates per acre.

In North Carolina some spraying is done, and it is considered profitable, not only as a measure for preserving the foliage but also because berries from sprayed fields have less rot, are more attractive because of their greener caps or hulls, and are free of black-seed. Spraying has tended to prolong the harvest season, thereby increasing yields. In this State spraying must begin during the latter half of February or early March, when the first signs of new leaf growth appear, and continue at 10-day to 2-week intervals until the first berries are about half their mature size.

Bordeaux mixture has not been known to cause injury to strawberry plants; on the contrary the spray material appears to have a stimulating effect, as sprayed plants when growing in some soils are more vigorous and possess a greener color. Spraying may be done during the blooming season without injury to the blossoms.

In regions where leaf spot and leaf scorch are not especially destructive or where they cause damage only occasionally, it is often more profitable to take only such precautions as will merely reduce the disease. Mowing off and burning the old leaves immediately after harvest is practiced in some districts when the field is to be

retained for another year. As soon as the foliage is dried and a good breeze is blowing in the direction the rows run, a fire should be started on the windward side. When burning is done in this way the fire will pass quickly and the roots and crowns are not likely to be injured. The foliage should not be burned, however, when the ground is very dry or when the leaves are damp.

Frequent renewal of strawberry fields will help prevent epidemics of foliage diseases. Since the fungi causing leaf spot and leaf scorch are not known to attack any other field or garden crop, it is likely that if disease-free plants are set in a new field they will remain reasonably disease-free during the 1 to 3 years the field is usually cropped. Ordinarily these two strawberry diseases are introduced into new fields on the young plants when they are set. Most of this infectious material can be eliminated if all expanded leaves (or at least those that show spots) are removed and the central cluster of partly folded leaves is dipped in bordeaux mixture just before the plant is set. As a further precaution, the new field may be sprayed at monthly intervals with bordeaux mixture during the period of bed formation. Spraying during this period is a simple task, as there are not many plants to spray until the runners begin to be established. The building up of infection sources during the first and second fruiting years, as the result of the introduction of chance spores from outside sources, would be slow in comparison with the rate of increase if the disease were present on the leaves of each plant at the time of setting.

In some sections in the South strawberries are grown in beds for the propagation of plants for fall setting. Under this system in Florida the summer-grown plants are sprayed with bordeaux mixture at 2-week intervals during the summer to control leaf scorch; then after the plants are set in the field it is sometimes necessary to make two applications, one shortly after setting and the other about a month later. In southern Louisiana the first summer spray is applied about the first of August, and spraying is repeated at intervals of 10 to 15 days while the plants are in the propagating beds.

Selection of resistant varieties for planting is another means whereby the amounts of these two foliage diseases can be either reduced or largely eliminated. There is considerable difference in the susceptibility of varieties to them. Some take the diseases readily, whereas others are resistant to one or both.

In reference to the susceptibility to leaf spot, some of the varieties may be classified as follows: Resistant—Aroma, Daybreak, Fairfax, Fairmore, Howard 17 (*Premier*), Klonmore, Massey, Pearl, Progressive, and Rockhill; slightly susceptible—Blakemore, Catskill, Chesapeake, Dorsett, and Missionary; moderately susceptible—Beaver, Dunlap, Gandy, Heflin, Joe, Lupton, Parsons, and Pathfinder; and very susceptible—Glen Mary, Klondike, and Marshall.

Varieties cannot be so definitely classified as to susceptibility to leaf scorch. The following varieties may be considered as resistant: Blakemore, Catskill, Chesapeake, Dorsett, Fairfax, Fairmore, Heflin, Howard 17 (*Premier*), Klonmore, Lupton, Mastodon, Pearl, and Rockhill; whereas Aberdeen, Klondike, Joe, Massey, Missionary, and Redheart are more susceptible.

Preparation of Bordeaux Mixture

> **PRECAUTION:** Bordeaux mixture may cause gastric disturbances if taken internally, and all unused portions should be disposed of or covered in order to be inaccessible to children and animals. It is also somewhat irritative to the eyes and skin.

Bordeaux mixture is a spray solution to be made at home and used while fresh. In the preparation of the spray, copper sulfate (bluestone), lime, and water are used. The strength of the mixture varies somewhat, depending upon the crop to be sprayed. The usual strength for strawberries is made with 4 pounds of copper sulfate and 4 pounds of lime to 50 gallons of water. The powdered and the fine-granulated copper sulfate, sometimes termed the "snow" form, are preferred, as both dissolve quickly in water. The most convenient and available type of lime for this purpose is that used in the builder's trade and known as hydrated lime. To prepare a 50-gallon spray tank of bordeaux mixture, fill the tank or barrel about two-thirds full of water, pour in 4 pounds of copper sulfate, and stir until all is dissolved; then add the 4 pounds of lime, stirring at the same time; when the mixture changes to a light-blue color, finish filling the tank with water. The spray solution is then ready to apply.

A small quantity of bordeaux mixture for spraying home plots of strawberries can be made by using 2 level tablespoonfuls of copper sulfate and 6 of hydrated lime to each gallon of water. The spray mixture can be made in the spray receptacle as described for making a larger amount. If an insecticide, or a spreading agent, such as soap or casein, is to be used, it should be added to the bordeaux mixture as the last step.

LEAF BLIGHT

Leaf blight [3] is easily distinguished from other diseases appearing on strawberry leaves by the large red to brown spots surrounded by a purplish margin. The spots may range from one-fourth of an inch to 1 inch or more across. They may also range in shape from almost circular to elliptical or triangular, depending on their age and their position on the leaflets. When the infection occurs near the margin, the dead areas are often triangular, being limited to the leaf tissue between two veins; but if the infection occurs away from the margin the dead areas are usually circular or elliptical, with the long axis on the midrib or one of the large veins (fig. 3).

The disease sometimes causes considerable blighting of the foliage on old fruited plants after harvest, but it seldom does damage to young runner plants or to old plants if vigorous. The damage done by this disease is not usually extensive enough to warrant remedial measures.

[3] Caused by *Dendrophoma obscurans* (Ell. and Ev.) H. W. And.

FIGURE 3.—Strawberry leaf blight on the upper surface of leaves. Such large brown or reddish spots are usually found on old plants.

VIRUS DISEASES

A large group of plant disorders causing more or less definite symptoms usually manifested as yellowing or mottling, distortion and spotting of leaves, and dwarfing of the entire affected plants, are known as virus diseases. The property or agent causing these diseases is within the plant tissue and can usually be transmitted from diseased to healthy plants by one or more methods. There are two important virus diseases of strawberries known in the United States, both present in the region west of the Rocky Mountains but not known in other parts of the country. Controlled experiments have shown that both strawberry virus diseases can be transmitted by a species of strawberry louse or aphid (*Capitophorus fragaefolii* (Ckll.)). The diseases have been given names that suggest some symptom of each, viz, crinkle, and yellows. Since the symptoms of the two diseases, as reported, vary according to season of year, age of plants, and locality where plants are grown, there is no easy method to describe the diseases to enable them to be recognized with certainty at all times. To complicate matters further, a field may contain both diseases; in fact it is not unusual to find both in the same plant, which then will show some combined symptoms of both.

CRINKLE

Crinkle occurs in some strawberry sections of all three Pacific Coast States. In general, an affected plant is of a lighter shade of green than normal ones. The leaves have a tendency to lie flat on the ground and the petioles are short, giving the plant a dwarfed appearance. Some of the leaves are distorted or wrinkled; they may be arched downward or cupped upward (fig. 4).

Two characteristic symptoms of crinkle definitely identify the dis-

FIGURE 4.—Crinkle: *A*, Marshall strawberry plant showing crinkling and spotting caused by the crinkle virus; *B*, normal plant. Photographed by S. M. Zeller.

ease. There are usually some wrinkled or distorted leaves on affected plants. Such leaves show mottling of lighter green or yellow; the veins become cleared or yellow and translucent. This clearing may even extend into the finely netted veins. The other symptom, which is perhaps always present in crinkle-affected plants, is that of faint yellowish spots or clearings, sometimes termed "stippling," in the leaves. These always show on the youngest central leaf as very small spots about the size of the head of an ordinary pin or even smaller, and are best seen by holding the leaf to be examined toward the light. These small areas enlarge somewhat with the expansion of the leaf, and later the central portions of the spots may die.

Symptoms of crinkle show more clearly during the fall and early spring. Young runners from infected plants develop the stippled appearance soon after taking root, and the youngest leaf of an older plant will begin to show this symptom in about 2 weeks after becoming infected.

Infected plants do not die but are less productive than normal ones. Once infected, plants never recover and all runner plants developing from them are diseased. With some diseased plants in a field infested by the strawberry aphid a rapid spread may be expected.

Recommendations for Reducing Losses

For methods of reducing losses, see page 11.

YELLOWS, OR XANTHOSIS

Yellows, or xanthosis, another virus disease of strawberries transmitted by the strawberry aphid, is prevalent from Puget Sound to southern California.

The appearance of the disease varies considerably throughout the year as influenced by temperature; the disease also varies according to the variety affected. In the Marshall type of strawberry, the variety grown most widely in the Pacific coast strawberry region, the disease shows certain characters whereby it can be recognized and identified with considerable accuracy. In general, the affected plants are dwarfed and somewhat yellow (fig. 5). The infected plants are often grouped in short or sometimes in long sections in a row where all plants are dwarfed. Healthy plants between the dwarfed sections are normal in size and color. Fields totally infected are uniformly dwarfed. The dwarfing effect is due to shorter leaf stems or petioles and smaller leaves. Affected leaves tend to lose their pointed tips and may be cupped upward; the centers are dull green and the edges yellow. Often one leaflet of diseased leaves is smaller than the other two, and the youngest central leaf is usually twisted or the leaflets are curled.

High air temperature has considerable influence on the appearance of yellows-diseased plants, tending to obscure partly or entirely the symptoms. Upon return of cooler weather in the fall the symptoms reappear.

As with crinkle, when strawberry plants become infected with yellows they never recover and all runner plants developing from them are diseased. The fruit does not attain full size and quality, and the yield is reduced. There is no known means of cure.

Recommendations for Reducing Losses

The strawberry aphid, which plays such a large part in the spread of crinkle and yellows, develops in enormous numbers during the winter and early-spring months and almost entirely disappears by late spring or early summer. The growers can profit by delaying

FIGURE 5.—A Marshall strawberry plant showing symptoms of a virus disease known as yellows, or xanthosis. (Photographed by A. G. Plakidas.)

the setting of new fields until after the aphids have disappeared. If this practice is followed there will be very little spread during the first year. Roguing abnormal plants during the first summer in new fields will help. An advantage will also be gained if new fields can be planted at as great a distance as practical from old infected ones. Roguing is not considered practical after the first season of growth.

The most promising method available at the present time for reducing losses from virus diseases in the Pacific coast strawberry sec-

tions is to grow under rigid State regulations and supervision, and preferably in isolated places where aphids are not abundant, all plants intended for sale to the public.

NONINFECTIOUS LEAF VARIEGATION, OR JUNE YELLOWS

Leaf variegation, or June yellows, is not an infectious disease but is due to a hereditary factor or character present in certain varieties. Normal green plants may become variegated at any stage.

FIGURE 6.—Leaf variegation, or June yellows, a noninfectious disease of strawberries, characterized by mottling with yellow and green. Note the portion of a normal leaf on the right.

The most prominent and characteristic symptoms of this condition are mottling and streaking with yellow and green, the exact appearance of which differs with variety and season. Early stages of leaf variegation may show as faint streaking and mottling of the new leaves with yellow or cream and green. The affected leaves show less and less green color and finally become golden or light yellow, with very little or no green. Affected plants have never been known to recover but may live for two or three seasons. Badly affected plants become stunted and unproductive and finally die. Normal plants of such susceptible varieties as Blakemore and Howard 17 (*Premier*) possess the character for yellowing, and there is no way to

predict when a plant or its progenies will turn yellow. All runner plants originating from a yellow plant show variegation in some degree (fig. 6).

Although the condition has been known for many years, it was considered of minor importance until the introduction of Howard 17 (*Premier*) and Blakemore, two varieties now widely grown east of the Rocky Mountains. Roguing was first recommended for holding the variegation in check in Blakemore, but after repeated trials this practice was found ineffective and was abandoned. The Blakemore sports to the yellow color much more frequently than any other important commercial variety. Most everbearing varieties possess the character for sporting to yellows or variegation.

RECOMMENDATION FOR REDUCING LOSSES

There is no known cure for leaf variegation, or June yellows. Certain strains or stocks of Blakemore and Howard 17 are at present comparatively free of this tendency to turn yellow. Growers should use the yellows-resistant strains for planting, as this is the only known way in which the trouble can be combated.

DWARF, OR CRIMP, CAUSED BY NEMATODES

Dwarf, or crimp, which includes bud nematode diseases of strawberries, was formerly known under a number of other local names, all based more or less on the symptoms or the locality where prevalent. Of the two names now most commonly used, the term "dwarf" probably has the wider usage. It is, however, somewhat confusing, as there are several parasites and agents causing dwarfing of strawberry plants—namely, the fungus causing red stele root disease, the cyclamen mite, root-eating insects, and the agents causing virus diseases.

There are two types of dwarf, or crimp, recognized in this country. One, the summer dwarf, is favored by high summer temperatures and is primarily a disease of the South, where it has been known for many years; the other form is spring dwarf—it appears primarily in the early spring. The two diseases are distinct, being caused by different but closely allied species of nematodes that have their greatest increase at different temperatures.

The nematodes, or eelworms, causing the two diseases are microscopic in size and live between the tightly folded young leaves. The nematodes inhabit the innermost part of the buds and feed by sucking the sap from the very young plant tissues. The constant irritation and injury of the young folded leaves cause dwarfing and other malformations that show after the leaves unfold.

SUMMER DWARF

Summer dwarf [4] is confined to the strawberry-growing regions where the winter climate is mild and zero temperatures are absent or infrequent. The disease persists regularly and is found commonly from North Carolina and Arkansas southward. The nematode lives through mild winters as far north as southern Illinois, Washington, D. C., and Delaware. This form of dwarf has also been observed

[4] Caused by *Aphelenchoides* sp.

in southern California in some strawberry fields where the planting stock orginated from nurseries in the Southeast (fig. 7).

Plants infested with the summer dwarf nematode usually appear normal during the first 2 or 3 months of the spring growing period. At that time there are only a few nematodes in the buds; but the

FIGURE 7.—Symptoms of summer dwarf as it appears in August. Note the distorted crown leaves and the more normal outer leaves formed in early spring.

population increases as the weather becomes warmer, and the leaves of infested plants that develop during the summer and early fall show the result of the injury done by the heavy summer infestation; these leaves are narrow, twisted, glossy, stiffer and greener than normal ones, the petioles are short, and some leaves are reduced in size to mere rudiments. The malformed leaves occur in the center of the plant and are surrounded by a ring of normal, or nearly normal, leaves formed in early spring when the nematode infestation was low. Figure 7 shows extreme symptoms of summer dwarf. In infested

fields there are all degrees of dwarfing, from such extreme cases to plants showing only one or two crown leaves slightly abnormal. The symptoms become somewhat masked in the fall when the mean air temperature falls below the optimum for development of the nematode. New crown leaves that unfold then are about normal in size and shape.

Infested plants are weakened by the injury to the leaves; therefore they form fewer flower buds to produce fruit. Severely dwarfed plants produce no fruit and few runners, and some plants are killed outright.

Although summer dwarf is common throughout the South there is now only an occasional field with a sufficient number of infested plants to influence greatly the yield. Most southern strawberry growers know the disease and make a practice of cutting out affected plants when hoeing and weeding their fields. Moreover, commercial plant growers and plant-inspection officials in States where plants are grown for sale are more alert now than formerly to the importance of producing disease-free plants; consequently there is now undoubtedly less summer dwarf than a few years ago, when in Louisiana it was estimated that 10 percent of the strawberry plants in the main berry section were infested, and in some parts of the South it was not uncommon to find from 50 to 75 percent of the plants diseased in some old fields.

Recommendations for Reducing Losses

For methods of reducing losses from summer dwarf, see page 16.

SPRING DWARF

As the name indicates, spring dwarf [5] is primarily a strawberry plant disease the symptoms of which show best during the early part of the growing season, when the greatest damage is done.

Spring dwarf is caused by a nematode very similar to the one causing summer dwarf, and the method of attack and general symptoms produced are also similar. One major dissimilarity of the two diseases is the difference in the season of the year when symptoms of the diseases show—those of one in early spring and those of the other from midsummer to autumn (fig. 8).

The nematode causing spring dwarf can persist through winters with subzero temperatures and through summers with relatively high temperatures. It therefore has a wider range than the one causing summer dwarf, which is confined to regions not visited by subzero winter temperatures. Spring dwarf persists regularly along the Atlantic seaboard from Norfolk, Va., to the Cape Cod, Mass., district.

Spread of spring dwarf is apparently on the increase at the present time. It was first observed in Massachusetts in 1932. In 1938 this strawberry disease was found to be established in Connecticut and New Jersey, and the Eastern Shore section of Delaware, Maryland, and Virginia. Since then it has been observed in at least one field in Georgia, Michigan, and North Carolina, respectively. The persistence of the disease in such widely separated regions suggests the assumption that this species of bud nematode is capable of greater adaptation to climatic conditions than the one causing summer dwarf.

[5] Caused by *Aphelenchoides fragariae* (Ritzema-Bos) Christie.

The nematodes causing spring dwarf increase rapidly during the periods of cool weather in late fall and early spring, and when the first spring leaves unfold several thousand nematodes may be found in a single bud. Leaves developing from the infested buds are small, narrow, twisted, and glossy. The blossom buds are killed before they show. Infested plants produce little or no fruit. Some plants are killed during the period of heavy infestation; but usually they survive, and upon the return of hot summer weather, which brings about a decrease in the number of nematodes, they show recovery and finally develop into good plants and produce normal-appearing runners.

FIGURE 8.—Symptoms of spring dwarf. The distorted crown leaves were the first ones to form in the spring; the outer leaves had developed during the previous year.

However, most of the runners are infested, although they may not show distinct symptoms until the following spring.

Recommendations for Reducing Losses

Since the causes and methods of spread of summer dwarf and spring dwarf are similar, control measures recommended for one will also apply to the other.

The most common method of spread of the dwarf, or crimp, nematodes is through the runner plants. Most runner plants originating from an infested mother plant are also diseased. The runner buds become infested while they are still within the crown, and the nematodes are carried along with the terminal bud as the runner elongates. Some of these diseased plants are dug for sale or for planting, and the disease is thus introduced into new areas or into new fields.

The diseases are also thought to be spread by heavy rains that flood a field for several hours. Plants in low portions of the fields or in depressions are apt to become infested in this manner, provided there are diseased plants at higher levels in the field.

The grower, if he is familiar with symptoms of dwarf, can do some good by roguing diseased plants as a routine when hoeing and weeding during the first year after the field has been set. Affected plants that are cut out should be removed from the field, as the nematodes may remain alive but dormant in dried plants and revive even after a considerable time if the plants become wet.

In sections where growers use their own plants or obtain plants from neighbors for setting new fields, they sometimes inadvertently perpetuate or introduce the diseases. It is inadvisable to use for setting plants that have been taken from a field known or thought to be infested by bud nematodes.

Undoubtedly the most promising method of decreasing the loss from dwarf in the country as a whole is by systematic and intelligent inspection of all strawberry plants offered for sale and certification of only those fields showing no dwarf at the time of inspection. Inspections must be made at a time of the year when the symptoms show best. This requirement would necessitate two inspections each year in regions where both types of dwarf persist. Late-summer or early-fall inspection should detect an infestation of summer dwarf, whereas an inspection made soon after the strawberry plants start new spring growth is necessary before certifying for freedom from spring dwarf.

ROOT DISEASES

A number of different fungi have been isolated from diseased strawberry roots in various parts of the country. These fungi are for the most part common soil-infesting forms and are known to attack plants other than strawberry. Systematic rotation of crops is about the only practical means known to remedy this trouble. There are no simple diagnostic methods by which growers can separate or identify the various root diseases, except the one known as red stele, or red core. This disease is widely distributed in important strawberry-growing regions and is caused by a fungus, as far as is known, parasitic only on strawberries.

There has been a tendency for a number of years to attribute to root rot and black root some strawberry troubles the causes of which were not well understood. There is no doubt that fungi cause damage to strawberry roots or even kill plants. It is believed, however, that some of the so-called root rots and black root diseases are sometimes confused with and complicated by winter injury, drought injury, injury from soil too acid or too alkaline, and fertilizer injury. In the northern strawberry sections, where low winter temperatures and frequent alternate freezing and thawing of the roots occur, black root constitutes a major strawberry trouble. Winter injury to the roots can be largely prevented by mulching with straw, wild hay, or pine needles. About 2 tons of straw per acre is adequate, except in the upper Mississippi River region, where as much as 6 tons is used to give protection against cold. It is advisable to apply the mulch in November or December, before the occurrence of temperatures sometimes as low as 15° F. in the field.

RED STELE ROOT DISEASE

The term "red stele" is applied to a strawberry root disease[6] comparatively new to North America. It was first observed in this country in Illinois in 1932. It was found to be well established in Maryland in 1936, and during the following year it was found in Delaware, New Jersey, New York, Michigan, and Virginia. Since then it has been found in Arkansas, California, Kentucky, Indiana, Massachusetts, Ohio, Oregon, Pennsylvania, Tennessee, Washington, and Wisconsin. Seemingly, the fungus causing the disease is limited at present to the northern strawberry sections. The high summer temperatures of the South are thought to be the most important factor restricting the disease.

The most obvious above-ground symptoms of plants affected by red stele are early-spring stunting or dwarfing and the wilting and dying of the older leaves. The new spring leaves on badly infected plants are small, have short petioles, and are slightly bluish in color. Diseased plants appear to decrease in size as the spring season advances. This striking symptom is often observed by growers to result from the dying and drying up of the previous season's normally large leaves and from the simultaneous production of new short-petioled spring leaves in the center of the plants. The stunting is more accentuated in the lower levels of the field where the soil remains saturated or flooded for several hours after heavy rains. Badly affected plants produce little or no fruit, and many die during the first dry period in the spring.

Since the fungus attacks only the root system, the above-ground symptoms are the result of the damage done to the roots. The fine, fibrous feeding roots are destroyed first, and only the coarser rat-tail-like ones are left. From the small roots the fungus slowly advances into the larger ones, invading mainly the central cylinder or stele, killing that portion and causing it to turn dark red. The outer part or bark of the large infected roots continues for a while to appear healthy, but later this part dies too and turns dark, beginning at the tips or lower ends of the root (fig. 9).

Stunted strawberry plants suspected of being infected by the red stele root fungus should be taken up with the root system intact for diagnosis. If there is an abundance of small white feeding roots and no rotting of the larger roots the stunting is probably due to some other cause. If the small fibrous roots are discolored or have disappeared, leaving only the rat-tail-like large roots, and, further, if the central part of the large roots is dark red, then the stunting is doubtless due to the red stele fungus. The red color of the central portion of an infected root may extend throughout its length, or the color may show only a short distance above the dead tip. This character of reddening of the root interior is best demonstrated by splitting the root with a knife blade or by stripping off the outer portion of the root with the thumb nail. This dark-red color of the central part of affected roots is not known to be associated with any other strawberry disease, and the symptom is considered the most trustworthy one for making field determinations (fig. 10).

Some persons confuse discoloration of the crown tissues with symptoms of the red stele root disease. The fungus causing red stele

[6] Caused by *Phytophthora fragariae* Hickman.

FIGURE 9.—Red stele root disease of strawberry: *A*, Nondiseased plant; *B*, diseased plant. Note the absence of small feeding roots in *B*, as compared with the normal root system.

is not known to invade the crown or stem, and any discoloration of those tissues should be attributed to some other cause.

The causal fungus is favored by cold, wet soil and spreads most actively in cold rainy periods in late fall, in winter except when the soil is frozen within the area of root penetration, and in early spring. No

FIGURE 10.—Strawberry roots affected with the red stele root disease. *A*, Diseased roots showing dead, discolored tip ends; upper portion of roots not discolored. *B*, Diseased roots split lengthwise, to show reddened central portion. *C*, Normal roots split lengthwise, to show absence of red center. (All slightly enlarged.)

evidence of spread of the disease in the summer months has been observed. Plants slightly to moderately infected in early spring partially or fully recover during the warm months, only to suffer another attack in the following spring.

This fungus develops two types of spores. One type is produced on infected small roots in winter and spring when the soil is saturated with water and the temperature is relatively low. The spores are

motile and are carried from diseased to healthy plants by water movements within the soil or by surface water draining from higher areas of infected plants to others at lower levels. Another type of spore produced within the reddened interiors of the roots is believed to maintain the fungus in a dormant stage through the summer.

Recommendations for Reducing Losses

After the red stele disease is once established in a field of strawberries there is no known means of effecting a cure. Infested fields should be plowed under and some other crop planted. A grower should take every precaution possible to keep the disease from his farm. As the disease can be spread from one field to another by setting infested plants, care should be exercised to obtain disease-free plants for planting new fields. Spores that form within the red center of diseased roots will live for a considerable length of time in the dead roots and in the soil. It is, therefore, not advisable to replant a field to strawberries for at least 3 or 4 years after it has once grown a crop of diseased plants. Since the fungus is not known to attack any plant except strawberry, other field or garden crops may be grown on infested soil without danger of infection.

As in the case of dwarf, the most promising line of attack for increased control of red stele root disease is systematic spring inspections of nurseries within the regions where the disease occurs and certification of disease-free plantings only.

Standard commercial varieties of strawberries exhibit different degrees of susceptibility to infection by the red stele fungus. Although most varieties are highly susceptible, three (Aberdeen, Pathfinder, and Beauty) are known to have outstanding powers of resistance. Aberdeen seems to lead in this respect; in fact as far as known to the writer there is no record of the fungus ever having been found in roots of this variety. Furthermore, the Aberdeen has resisted artificial infection under conditions where other varieties succumbed. Although not a very desirable variety except for home consumption, it can be grown without showing damage in soils thoroughly infested with this root parasite. The other two varieties are not immune, but they possess enough resistance to make satisfactory growth and yields in soils infested with the fungus.

ROOT KNOT

Root knot is a disease caused by a different nematode[7] from those causing dwarf or crimp. The root knot nematode infests only the roots, causing enlargements at various places, especially the tips of the smaller roots. The galls on strawberry roots are usually much smaller than those on most other plants; in fact, they may not be at all conspicuous. This disease is more frequently found in southern strawberry fields than in those in regions farther north.

Recommendations for Reducing Losses

Root knot does not often cause severe damage to strawberry plants. When such damage does occur, it is usually the result of setting plants in a field already heavily infested by some previous crop, such as to-

[7] *Heterodera marioni* (Cornu) Goodey.

mato or tobacco. Perhaps the most serious feature about root knot on strawberries is not injury to the plants but the danger of carrying the nematodes in infested plants to fields or regions not previously infested.

Southern growers can avoid trouble with root knot by establishing new fields with nematode-free plants on recently cleared land. If new soil is not available, then a field should be selected that for 2 or 3 years in succession has grown crops highly resistant or immune to the root knot nematode. All grass relatives, such as corn, barley, oats, sorghum, and Natal grass, as well as the velvetbean, cowpea (Brabham and Iron varieties), peanut, and Laredo soybean, are highly resistant to this nematode.

DEAD CAPS, OR SHUCKS

A pack of berries with dead, dried, black caps or hulls is unattractive, is given a lower grade by the inspector (in States where berries are inspected before marketing), and is sold at a lower price than if the caps were green. Dead caps are not always a sign of disease but may be caused by several factors. Some varieties of strawberries, such as Klondike, Missionary, and Blakemore, naturally have weak, frail sepals that are easily killed by high temperature and low humidity accompanied by wind. A large proportion of the dead caps, however, are caused by common mold fungi, including the fungus causing gray mold of berries, that causing leaf blight, and other semisaprophytic fungi. The parasitic strawberry fungi, such as those causing leaf spot and leaf scorch, seem to be less frequently associated with injured caps.

CONTROL MEASURES

The condition of the caps can be greatly improved by making two applications of 4–4 50 bordeaux mixture 10 days apart, beginning when the first blossoms open. **(Do not use this spray without reading precaution on page 7.)** Although it is doubtful whether growers are often justified in spraying solely as a protection against injured caps, it has been repeatedly observed that berries from fields sprayed for control of foliage diseases have better caps and are much more attractive than unsprayed ones grown under similar conditions.

BLACK-SEED

A minor disease of strawberry fruits, but occasionally important, caused by the leaf spot fungus,[8] has been observed in the Middle Atlantic Coast States. The name black-seed has come to be generally used by growers, owing to the black spots about one-fourth of an inch in diameter surrounding the seeds, or achenes. The berry pulp is discolored a short distance below the black surface, but no general decay of the infected berries takes place. Usually only 1 or 2 spots occur on affected berries, but there are occasionally as many as 8 or 10. Spotted berries detract from the appearance of the pack and therefore must be discarded as culls. The abundance of berries affected by black-seed varies through the season. At some pickings one-fourth of the berries may be spotted, whereas at others none are found. The spots are conspicuous on green fruits and on ripe fruits

[8] *Mycosphaerella fragariae* (Tul.) Lindau.

of light-colored varieties. The varieties Blakemore and Pathfinder have shown greater susceptibility than others (fig. 11).

CONTROL MEASURES

The spray schedule recommended for the control of leaf spot and leaf scorch gives very satisfactory control for black-seed (p. 5).

FIGURE 11.—Black-seed disease as it shows on green strawberries.

FRUIT ROTS COMMON IN THE FIELDS

Commonly associated with field rots of strawberries are three or four fungi that not only cause decay of the ripe berries but also attack the green berries. Fruit rots perhaps cause greater loss to strawberry growers, especially in the South, than all other diseases combined, and the growers can do little to prevent the losses. Epidemics of field rots ordinarily follow prolonged periods of rain and cloudy weather, accompanied by temperatures suitable for the particular fungus. Dry weather or occasional daytime showers, if occurring early enough in the day for the foliage to dry before night, offer a much less favorable environment for the development of rots. Rots of the more important types show certain characteristics whereby they can be distinguished.

GRAY MOLD ROT

The most common and widely distributed fruit rot of strawberries is that caused by the gray mold fungus.[9] This disease affects both green and ripe berries. It usually starts in the part of the berry that is next to the ground or that touches another decayed berry or a dead leaf. It is first noticed as a light-brown, rather soft spot. The rot spreads through the berry and is not localized in any particular portion. After the berry is wholly rotten it begins to dry out and becomes firm and tough and of a uniform color throughout. At this stage it is almost entirely covered by gray powder, or dusty-appearing fungus growth, the well-known gray mold. This disease is most common in the cooler strawberry-growing regions. It is often very destructive in North Carolina, Maryland, Delaware, New York, and New Eng-

[9] *Botrytis* sp.

land, where it is not unusual for it to cause a loss of 10 percent or more of the crop. The disease is especially favored by moisture and may become destructive in any of the large strawberry-growing sections during continued wet weather.

The growth of gray mold cannot be entirely prevented by ordinary refrigeration. Under the conditions in many refrigerator cars, strawberries affected with this disease often become covered with an abundant growth of fluffy gray mold, which is very conspicuous and seriously hurts the sale of the entire load. Consequently, it is important that berries affected with gray mold be carefully culled during picking and packing.

The injury caused by gray mold is not confined to the fruit. The blossoms are frequently blighted by this disease, and under favorable conditions leaf and flower stalks may be affected and the whole plant thus seriously injured.

TAN ROT

The so-called tan rot [10] is important, especially during rainy seasons, in Louisiana, Florida, Arkansas, Virginia, Maryland, and North Carolina. It may attack either green or ripe berries and forms slightly sunken tan-colored areas which usually develop on the side of the berry. The rot extends into the pulp so that the rotten portion forms a cone with its base at the surface of the berry. The outer layer of this diseased area becomes soft, and, as the core of the rotten portion is held together by the rot fungus, it is easily removed intact with the point of a knife or pencil. This characteristic serves to identify this trouble readily.

HARD ROT

Hard rot [11] is sometimes serious in the strawberry fields of central Florida and has been found in North Carolina, Arkansas, and Tennessee. As the rot is caused by a soil fungus, it almost always occurs on the side of the berry that comes in contact with the soil, and a small quantity of soil will usually be found clinging to the decayed spot.

The affected berries are generally one-sided and show a hard brown rot separated from the sound portion of the berry by a distinct line. The portion of the berry not actually penetrated by the rot fungus remains unchanged both in appearance and in taste.

LEATHER ROT

Leather rot,[12] which has been found in Alabama, Louisiana, Mississippi, Arkansas, Missouri, Tennessee, Kentucky, Illinois, Maryland, and Virginia, is readily distinguished from other fruit rots by the bitter taste of berries that are even slightly rotted. This disease may affect both ripe and green berries in any stage of development. When green berries are affected all parts become dark brown over the affected areas, or brown at the edges, shading off into the natural green. Partly colored berries show the same light-brown color at the center, but the spot shades off into purple and finally to the red of the berries. If a berry affected with this disease is cut across, a marked browning of

[10] Caused by *Pezizella lythri* (Desm.) Shear and Dodge.
[11] Caused by *Rhizoctonia* sp.
[12] Caused by *Phytophthora cactorum* (Cohn and Lebert) Schroet.

the vascular strands is readily noted. This is usually accompanied by a less marked browning of the other tissues. At no time is there any clear line separating the diseased and healthy flesh, and the diseased portion cannot be easily removed, as in the case of tan rot. The disease is most noticeable after rainy periods, especially if the weather is warm. Leather rot has proved very serious in White County, Ark., and in Tennessee. During some years more than one-fourth of the crop in these localities has been lost.

RECOMMENDATIONS FOR REDUCING LOSSES

Experiments in spraying and dusting indicate that the amount of fruit rot in the field can be reduced, but since the rots are not of regular occurrence in any particular locality year after year, the cost of the treatment does not seem to warrant the practice.

Mulching the strawberry fields with straw, hay, pine needles, etc. is practiced in many sections of the country. The primary purpose of mulching in the Northern States is the protection of the crowns and roots against injury by low winter temperatures, but it also tends to prevent rot, especially those forms of rot induced by infection from certain fungi that apparently gain entrance to the berries from the soil. Berries lying on the soil are apt to decay if the soil is damp and, in addition, become covered with sand and other soil particles that detract from their appearance when picked. Sand on the berries is also likely to cause bruising and cutting, thus increasing the opportunity for infection by rot fungi. In the South, pine needles are used for mulch; they are put on just before the plants blossom, so that the berries will be on top of the mulch and not in contact with the soil.

A heavy growth of spring foliage, following a spring application of fertilizer rich in nitrogen, offers a favorable environment for berry-rotting fungi, provided a rainy period occurs about the time the berries begin to ripen. The shading effect of the thick foliage prevents rapid drying of the berries after rains and heavy dews, and forms suitable conditions for germination of the fungus spores and the infection of berries. Loss of fruit indirectly caused by too much spring foliage can be partly avoided by applying the fertilizer during the summer or fall.

Late spring frosts that injure the blossoms and green fruits are often indirectly responsible for the infection by the gray mold fungus, which causes much rotting of berries in the field. When the frost-injured flowers and berries die they are often overrun with the gray mold fungus, and myriads of spores are produced on the dead parts in the center of the plants, among and against later developing berries. Under such conditions nothing short of a rainless harvesttime will prevent some loss of berries by rotting in the field.

FRUIT ROTS IN TRANSIT AND ON THE MARKET

The various rots just described are all found to a greater or less extent on berries in the field. A very large proportion of the rotten berries in most cull piles are infected with one or more of the fungi just mentioned. Their relative abundance varies in different parts of the country and with weather conditions. In general, as mentioned on page 23 and as every strawberry grower knows, these field rots are

more abundant during or immediately after a period of wet weather. It is during such rainy periods that the greatest number of rotten berries must be thrown out as culls when the berries are sorted in the packing shed.

Serious as is the loss from rots in the field, it is not so costly as that from the rots that occur in transit and on the market. Field rot means a reduction in the size of the crop and some added cost in the packing shed. Rot that develops in transit, however, means that the labor of growing that much of the crop, as well as the cost of picking, packing, and hauling to the railroad, has been wasted. To this waste must be added the expense of loading in the cars and the cost of freight or express and of refrigeration. Often more important than any of these is the disastrous effect on the market of the presence of moldy or leaking berries in the crates offered for sale.

All of the field fruit rots described are known to develop to some extent in transit. Gray mold, because of its wide distribution and its ability to grow somewhat at the temperatures usually obtained in refrigerator cars, is the most important of all the brown rots in transit.

LEAK

One of the most important rots of strawberries in transit and on the market is that known as leak,[13] also called black mold and rhizopus rot. As its common name indicates, leak is characterized by the collapse of the berry and the loss of much juice. Even one or two leaking berries will stain a box and make it unattractive, and it is not uncommon for the juice to drip from boxes and crates of badly infected fruits. Spores of the leak or black mold fungus are almost always abundant in the air of packing sheds, fields, stores, and houses. Once inside the fruit, black mold will destroy a strawberry much more quickly than any other fungus now known. Fortunately, however, this fungus usually enters the berry only through wounds and grows very slowly at temperatures below 50° F. Control measures, then, must be directed toward careful handling and the maintenance of low temperatures.

RECOMMENDATIONS FOR REDUCING LOSSES

In some sections, notably Florida, cultural and trade practices make it necessary to wash the berries before they are packed. When this is done, the berries should not be dried after washing, but they should merely be allowed to drain for a short time and then should be packed while still moist and kept in the shade until they are delivered to the loading platform. It is important that the water in which the berries are washed should be changed frequently. Not only does dirty water contain sand that injures the berries in handling, but also it contains spores of different mold fungi, especially *Rhizopus*, which may cause rotting of the berries in transit.

Careful handling to prevent bruising and quick cooling after harvesting are both important but do not assure that the fruit will reach distribution without loss. The fruit must be properly refrigerated during long transit periods.

In transit it is desirable to keep the fruit temperatures below 45° F.; 40° is still better. These temperatures, however, are difficult to

[13] Caused by *Rhizopus nigricans* Ehr. ex Fr.

maintain in cars unless salt is used in the bunkers with the ice. For this purpose the quantity of salt added at the initial icing should be 3 percent in cool weather and 4 percent in warm weather. At subsequent re-icings 3 percent is as much as can safely be used.

A great aid in maintaining low temperatures of fruit in transit is to precool the fruit after it has been loaded into the car and before the shipment moves to market. This may be done in various ways, several of which are described in United States Department of Agriculture Technical Bulletin 525, Handling, Precooling, and Transportation of Florida Strawberries,[14] and California Agricultural Experiment Station Bulletin 600, Precooling and Shipping California Asparagus.

If the producer's markets are within 24 to 36 hours of the producing districts, he will find pertinent information in United States Department of Agriculture Circular 515, Handling and Shipping Strawberries without Refrigeration.[15]

[14] For sale by the Superintendent of Documents, Washington, D. C., at 10 cents a copy.
[15] For sale by the Superintendent of Documents, Washington, D. C., at 5 cents a copy.

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